

ON THE GROWTH AND REACTION TO GRAZING OF THE PERENNIAL
SALTBUSH, *ATRIPLEX VESICARIUM*. AN ECOLOGICAL STUDY
OF THE BIOTIC FACTOR.

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(Plates vii-ix; five Text-figures.)

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In this paper, the second of a series¹ dealing with investigations at the Koonamore Vegetation Reserve, the dominant plant over much of the shrub steppe formation (*Atriplex vesicarium*, the perennial saltbush) is discussed in relation to its arid environment. In particular the results of a new biotic factor, grazing by sheep, are considered.

The location of the Koonamore Vegetation Reserve and the general purpose of the investigations have already been described (Osborn, 1925). It is the Arid Flora Research Station of the University of Adelaide, to whom it was given in 1925 by Messrs. Hamilton, Wilcox Ltd., the then owners of Koonamore.

In a paper to appear shortly we shall deal with the results of five years work on the Reserve. The present investigation has been conducted from this base and has been carried out at intervals during the period April, 1928, to June, 1931. During this time the work has been supported by a grant from the Commonwealth Council for Scientific and Industrial Research.² The investigations herein described could not have been carried out without the kindness of the owners of the neighbouring sheep stations who readily allowed us access to their paddocks. It is not possible to mention all to whom our thanks are due, but we are particularly indebted to R. E. H. Hope, Esq., owner of Koonamore, and his manager, Mr. J. Hardy; to the owners of Melton and their manager, Mr. W. Smith; to the directors of the Mutooroo Pastoral Company; and to C. Wade, Esq., of the Panarammattee Pastoral Company. To these, and the many others who have helped us, we offer our sincere thanks.

¹ The first was "On the Autecology of *Stipa nitida*, a study of a fodder grass in Arid Australia". PROC. LINN. SOC. N.S.W., lvi, 1931, 299-324.

² My thanks are due to the Council for Scientific and Industrial Research for the generous grant which enabled the Koonamore investigations to be carried on upon an extended scale after my departure from Adelaide. I am also much indebted to the Council of the University of Adelaide for allowing me facilities for continued work at Koonamore after my appointment to Sydney.—T.G.B.O.

INTRODUCTORY.

The harmful results that may follow from the grazing by stock upon the perennial flora in dry regions has been the subject of considerable study, particularly in the United States of America. As early as 1910 Griffiths showed, as a result of his observations on a protected stock range in Arizona, that the indigenous perennials, which were popularly supposed to be in process of being driven out by aggressive annuals, were really succumbing to overstocking. He found that the perennial vegetation would return with protection.

Sampson and Malmsten (1926) showed that frequent and close cropping by stock was detrimental to both perennials and herbaceous plants on Western forest reserves. It led to soil impoverishment and erosion. Their work showed, amongst other things, that rotational grazing was important in preserving the natural plant cover.

The methods involved in the study of the reaction of shrubby perennials to grazing must necessarily differ somewhat from those employed in the study of herbaceous flora. Nelson (1930), in a paper contributed to the symposium on Range Ecology held by the Ecological Society of America, described the quadrat methods used. We have utilized information gained from quadrats, of which we have established a number, some under complete protection, others subjected to grazing in the open paddocks. These will be described shortly, but for the purpose of the present inquiry we have found the method less suitable than a modification of the line transect described below. We have also utilized a metre quadrat frame dropped at regular intervals along transect lines, but this, too, has been found unsuitable for perennial shrubs of the *Atriplex* type. The community that we have investigated is too open and the plants too gregarious for a method of dropped quadrat sampling to give a reliable picture of the community. Such a method we have found valuable in the study of herbaceous plants, e.g., in our work on *Stipa* (Osborn, Wood and Paltridge, 1931).

Over considerable portions of arid Australia saltbush is the most valuable plant. It is true that when other forage is available (grass and "herbage" in "good seasons"), saltbush is taken by sheep in the way of a browse and is not consistently grazed. It is palatable because of its salt content, and its protein content is high. In time of drought, it is the only fodder plant available to sheep. Moreover, it is the only perennial ground cover over vast areas and its destruction leads to a calamitous amount of drift and erosion.

Since the settlement of Australia by white peoples, a profound change has occurred in the biota (Osborn, 1929). This is everywhere marked, but in the arid portions it is particularly severe. An indigenous flora, evolved in an environment in which close grazing animals were absent, has been subjected to more or less intense grazing by large stock, sheep in particular, and rabbits. The changes that may be produced by an unduly severe incidence of stocking are profound. These have frequently been referred to because in a severe state the cumulative influence of the stock effect and an arid climate may destroy the whole plant community. Hitherto no attempt has been made to evaluate just what changes do occur in the permanent flora as a result of this new biotic factor. The purpose of the present paper is to give an account of these changes.

THE SALTBUSH COMMUNITY.

The chief physiographic features of the north-east of South Australia are the rocky hills and the wide open valleys and peneplains between them. The

soils of the hills are shallow and show immature profiles. They are derived from the quartzites and mudstones of Upper and Lower Precambrian age which form the basis of the ranges. The vegetation consists of a climax desert scrub of various sclerophyllous and xeromorphic species dominated usually by *Acacia* spp.

The soils of the plains, or properly speaking plateaux, are derived from these hills under a modern cycle of arid erosion. As a result of internal drainage these soils contain a good deal of silt and may be classed as sandy loams. The profile is a mature one with much travertine limestone in the B horizon. An analysis and profile has been given by us in a previous communication (1931, p. 308).

On these soils and on the gentler slopes of the hills, *Atriplex vesicarium* forms a true shrub steppe, in the main forming a pure community (Pl. vii, fig. 1), but occasionally mixed with other species, especially of *Kochia*, some of which assume local dominance (Osborn and Wood, 1923). Trees are very rare, but occasional bushes of *Eremophila* spp. and *Cassia* spp. may be found when the water relations are suitable. Following rains, various grasses and a host of ephemeral plants, the "herbage" of the Australian pastoralist, are to be found. Many of these develop most abundantly in the mounds of sand accumulated around the base of the saltbush. However, the only true permanent vegetation is the saltbush itself, or its other chenopodiaceous allies.

Atriplex vesicarium is an erect shrub whose average height and diameter (the mean of some 5,000 observations) is 32 and 34 cm. respectively. Occasionally much larger bushes are found. One growing on quadrat 100 at the Koonamore Vegetation Reserve, under complete protection from grazing for 5 years, is 160 cm. in diameter, though only 30 cm. high. This is an unusually large and sprawling bush, but several others may be found on the quadrats in the Koonamore Vegetation Reserve that are more than 100 cm. in diameter and a few of them reach 50-55 cm. high.

The plant has the characteristic anomalous secondary thickening of the Chenopodiaceae. The stems are rarely as much as 1 cm. in diameter; they are usually much more slender twigs. At all ages the wood is brittle and under stress it snaps easily with an almost clean transverse fracture. It is, therefore, easily damaged by mechanical means.

Generally only very young plants show anything like a main axis. The seedling and young plant (Text-fig. 1) show the early development of many buds from the basal part of the stem. The majority of plants show a number of slender, freely branching stems rising from the base which is usually surrounded by a mound of fine soil and sand deposited by the wind. This is always the case on grazed country, but in virgin areas the light surface layer of soil is sometimes more evenly distributed. It will be readily understood that a low-growing free-branching shrub such as *Atriplex* will hold the soil and accumulate a mound about itself. However, the plant is not a hemicryptophyte, but is chamaephytic in its growth form.

The stems appear whitish-grey, even greenish-grey after rain, though many dead twigs are generally present. These are a dark grey when they lose their bark, which they do rapidly after death. The leaves are obovate to broad lanceolate, 1-2.5 cm. long and 0.5-1 cm. wide. They are rather thick and fleshy to the touch when turgid. The leaf is never really green, but always more or

less grey and scurfy-looking owing to its dense cover of non-cuticularized hairs. These give the leaf a mealy white appearance which becomes more pronounced as the leaf loses water. Wood (1923 and 1932*b*) has shown that the plant has a low transpiration rate and that the leaves resist desiccation owing to a pentosan colloid complex (1932). The wilted leaves are freely shed by the



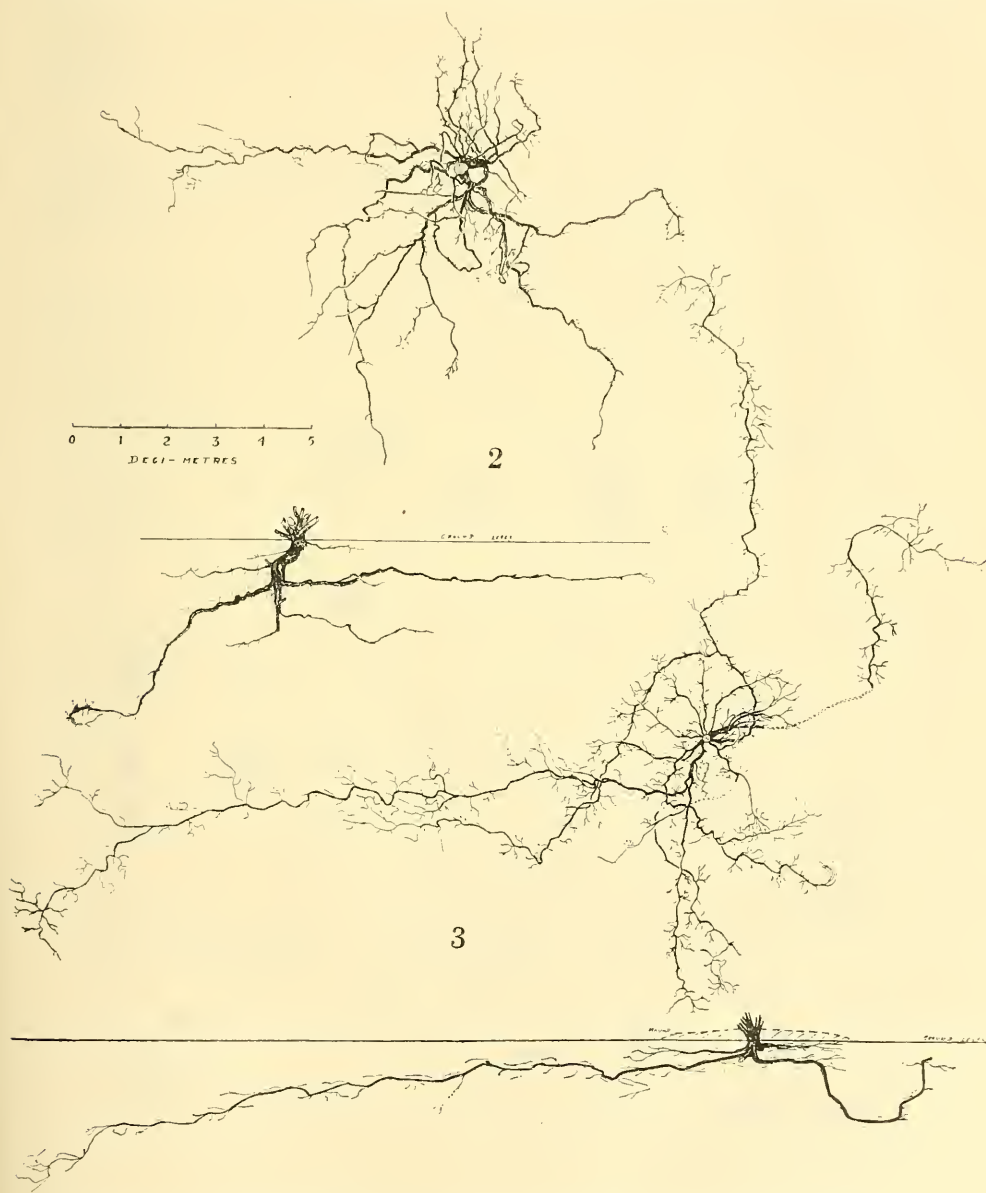
Text-fig. 1.—Seedling and young plant of *Atriplex vesicarium* showing early development of lateral shoots from the basal nodes. $\times \frac{1}{3}$. Miss C. Ure, *del.*

plants until a state of complete defoliation is reached (cf. Pl. vii, figs. 1 and 2, which shows an *Atriplex* covered penepalain in a wet season and during drought). At Frome Downs, a station about 60 miles to the north of Koonamore, which was visited by one of us (T.B.P.) in October, 1929, it was estimated, as a result of an extensive series of transect observations, that 95% of the plants were leafless.

These plants were in true virgin country, not yet stocked by sheep owing to lack of facilities for watering. Such plants are by no means all dead, like others described below; some would regenerate in good seasons throwing new shoots from the base of the stems. This drought deciduous habit is not usual in Australian arid plants, though it is paralleled in the case of such plants as *Astragalus* and *Fouquieria* (Maximov and Yapp, 1929).

Unlike that of most perennial plants in arid regions, the root system of *Atriplex vesicarium* is very shallow, never penetrating the nodular layer of travertine limestone, and mostly living within 10–20 cm. of the surface. It will be seen from Text-figures 2 and 3 that the surface extension is considerable, some of the longer roots being 2 metres in length. There is no tap-root, but a number of spreading laterals which branch at intervals. These tertiary members rarely branch, but produce numerous groups of short-lived feeding roots which are deciduous in time of drought, and renewed in wet periods.

The root system is probably largely non-functional during prolonged dry periods, but the plant possesses a secondary method of water absorption through its leaves. Wood (1925) has shown that shoots of *Atriplex vesicarium* gain weight when kept in an atmosphere of 85% saturation with water, a figure that

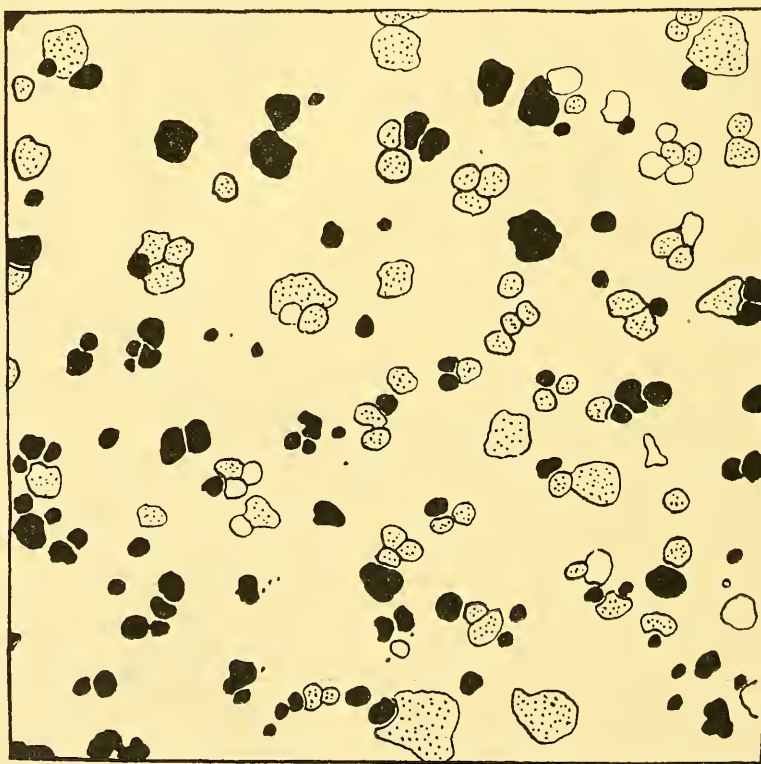


Text-figs. 2, 3.—Root systems of two plants of *Atriplex vesicarium* in plan to show the extensive development of surface roots bearing many fine lateral feeding roots, these being deciduous in drought. T.B.P. ad nat. del.

is the mean maximum humidity for the year at Koonamore. The regular occurrence of high maximum humidities, even during drought, is a feature of the climate at Koonamore (see below). The foliar absorption of water is possible because of the non-cuticularized leaves, and their high osmotic pressure. This Wood (19324) has shown to be as high as 50 atmospheres. The high osmotic pressure is due in part to the concentration of sodium and potassium chlorides in the leaves, which ranges from 20 to 30% of the dry weight (Wood, 1925). The roots are evidently selectively permeable to these chlorides, for the soil in which they grow contains only 0.02% NaCl.

Atriplex vesicarium is a dioecious species. The fruiting bracteoles are much enlarged and in the typical form covered by a pair of convoluted bladdery appendages. There is a good deal of variation in this feature, even on the same plant. Probably more than one ecotype exists, and possibly hybridization with other *Atriplex* species occurs, but the matter will not be dealt with here.

The shrub steppe community formed by *Atriplex* is an open one. The plants generally occur in clumps or groups of individuals of all ages with bare soil between them. This gregarious habit is due to the collection of fruits and



Text-fig. 4.—Chart of a quadrat of 100 sq. metres (Salt Creek No. 1) showing canopy area of the saltbush, and gregarious habit of growth. The bare ground between the bushes was at this time well covered by the annual *Gnephosis cyathopappa*. Healthy bushes shown black, wilting and partially defoliated plants stippled, dead bushes in outline only. Plate vii, figure 3, is a photograph of this quadrat. 19.viii.1928.

wind blown soil around the established plants (cf. *Stipa nitida*, Osborn, Wood and Paltridge, 1931), and not to any capacity of the plant to reproduce vegetatively. Text-figure 4 represents a quadrat with 10-metre sides set out and surveyed in a large open paddock (Sept., 1928). It shows well the gregarious habit of the plants and the open soil between them. The number of plants recorded as almost defoliated is to be noted. Plate vii, figure 3, shows the general appearance of the quadrat. The guide strings are stretched and the area divided into metre squares.

CLIMATIC FACTORS.

This section contains data as to the climatic factor relative to the growth of saltbush for the period covered by this investigation. A discussion of the full data will be given in a forthcoming paper on the general work of the Reserve.

Rainfall.

A table showing the rainfall month by month, the number of rainy days and of falls greater than 25 points, was included in our previous paper. It is sufficient to recall that the period covered by this work was one of exceptional drought and that an average annual rainfall at Koonamore (812 points) did not occur during the time of the investigation. From August, 1928, to November, 1929, both inclusive, only 176 points of rain fell. The five months, October, 1928, to February, 1929, were absolutely rainless and the next five months were without an effective fall, which we have defined as a fall of more than 25 points. A lighter fall is incapable of doing more than wet the surface of dry soil.

Temperature.

Temperature data were also given in the paper cited and need not be repeated here. The mean maximum temperature in the hot season ranges from 80° to 90° F. and from 60° to 70° in the winter. On an average for 8 years the number of frost days per annum is 53.5. A characteristic and important feature of the temperature is the high diurnal range, the mean annual range for which is 30.1° F. The greatest variation occurs during the summer months. This diurnal range has an important bearing on the humidity.

Humidity.

The humidity data are of special interest owing to the fact that high relative humidities are frequently recorded. This has an important bearing upon the water relations of *Atriplex vesicarium* because of its capacity for absorbing water through its leaves from nearly saturated air.

Relative Humidity.

Years.		Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sep.	Oct.	Nov.	Dec.	Ann.
1927 to 1931	Mean Max	93	82	83	87	87	91	91	87	87	81	80	84	85
	Mean Min.	37	35	34	39	43	51	47	42	37	35	31	35	39

It will be seen that the mean maximum humidity exceeds 80% in every month of the year. On the other hand, the mean minimum humidity falls below 40% each month, except May–August, which is the winter season.

The length of time during which high humidities prevail each day is obviously a feature of importance. The following table is derived from thermohygrograph records taken during the three-year period 1928–1931. It shows the mean number of hours per day in each month in which the humidity is greater than 80% and also, as an indication of the more rigorous arid conditions, less than 40%.

Table showing Mean Number of Hours per Diem when Relative Humidity > 80% and < 40%.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sep.	Oct.	Nov.	Dec.
Mean number hours humidity > 80%	In- suff. data.	3·9	4·5	7·2	9·6	8·7	8·1	6·2	4·7	3·8	3·8	3·1
Mean number hours humidity < 40%		6·9	5·9	3·1	2·4	1·0	1·8	4·1	6·0	6·9	8·9	7·6

The time during which the maximum humidity is highest lies between midnight and 7 a.m., reaching a maximum usually about the time of sunrise. The time of lowest humidity is between 2 p.m. and 4 p.m.

This variation in the humidity is a consequence of the high diurnal range in temperature and, since the relative humidity varies with the temperature, a more accurate picture of the degree of saturation of the air is given by the saturation deficit. The Meyer ratios, P/sd, have been plotted for Australia by Prescott on a map showing the isologs (1931, fig. 9). The ratio for Koonamore is about 25–30.

It is more important for an understanding of the water relations of *Atriplex* to know the mean saturation deficits throughout the year. The highest relative humidity is recorded at the time of minimum temperature and vice versa. The mean saturation deficits for each month given below are therefore calculated from the mean maximum humidity and the mean minimum temperature and mean minimum humidity and mean maximum temperature respectively.

Saturation Deficits in Inches of Mercury.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sep.	Oct.	Nov.	Dec.
Mean maximum temperature ..	92·4	91·0	83·3	82·1	63·4	61·9	59·4	65·8	67·6	80·1	84·3	86·7
Mean minimum humidity ..	37	35	34	39	43	45	47	42	37	35	31	35
Saturation deficit	0·95	0·95	0·75	0·68	0·33	0·27	0·27	0·36	0·41	0·65	0·81	0·85
Mean minimum temperature ..	57·8	61·4	55·1	46·6	38·7	35·7	34·6	35·8	36·8	45·4	53·8	55·4
Mean maximum humidity ..	93	82	83	87	87	91	91	87	87	81	80	84
Saturation deficit	0·04	0·05	0·07	0·04	0·03	0·02	0·02	0·02	0·03	0·05	0·08	0·06

These figures for the saturation deficits bring out clearly that every month, even during a severe drought and during the hot summer months, the air becomes almost saturated with water vapour for a portion of each day. This fact, we believe, accounts for the success and ubiquity of the saltbush. On the other hand, the aridity of climate is indicated by the high values of the saturation deficits during the daytime.

These data as to the high relative humidity and the length of time for which it is maintained throw an unexpected light on the environmental conditions under which *Atriplex vesicarium* grows. They show that even during a drought it is more favourably situated for obtaining water than might be expected. Nevertheless, during a drought of the extreme severity experienced during these investigations, permanent wilting, defoliation or even death, is the fate of the majority of the plants. There remains to consider the effect of grazing by sheep during such a severely adverse period.

METHODS.

The fundamental idea underlying these investigations upon the effect of grazing on saltbush may shortly be stated as follows. In any paddock the most intense influence of grazing and trampling by sheep (the "stock effect") will be felt around the watering place, since all the animals visit the dam or bore once or twice a day for water. Along lines radiating from the watering place the intensity of the stock effect becomes progressively less and less as the sheep pass away from the drinking place out into the paddock scattering as they go. It is a matter of observation, and so of common knowledge, that the average distance that sheep travel from water in the saltbush country is seldom greater than three miles, while the great majority are found congregated within two miles of the drinking places. During a wet winter, conditions may be different. The sheep may travel much further and remain for days in a distant portion of the paddock, depending on casual waters or the succulence of the herbage for moisture. But such conditions are exceptional. Owing to the size of the paddocks, seldom less than 4×5 miles, and often much larger, and the infrequency of the watering places (the sinking of wells or the excavation of dams is a costly process), there may be considerable areas virtually ungrazed or in a virgin state.

Around each watering place there can be defined four zones, as follows, differing from each other in the intensity of the stock effect:

1. The *A Zone*, immediately around the watering place, where inevitably the stock effect is very severe, in which the saltbushes are largely or entirely trampled out.
2. The *B Zone*, beyond A, in which the majority of the sheep feed, subjected to fairly heavy grazing and a good deal of trampling. The width of this zone depends upon the number of sheep carried in the paddock and also upon the physiography of the country around the watering place.
3. The *C Zone*, a lightly stocked area beyond the B Zone, which the sheep only visit occasionally and which is, therefore, not subjected to frequent grazing or trampling. The extent of this zone, as in the case of the B Zone, depends on the degree of stocking and on the physiography.
4. The *D Zone*, the area lying beyond the distances to which sheep normally travel. For the purposes of this investigation it has been considered as virtually ungrazed country. It affords a control or standard by which the stock effect may be gauged in the other zones.

Two desiderata were required to judge the effect of grazing upon saltbush within the four zones. These were (1) a classification of the bushes according to a scale of vegetative vigour, and (2) an inquiry into the variation in the numbers of bushes in each class of the defined scale.

As a measure of vegetative vigour, the degree of foliation of the bushes was utilized. The plants were grouped in the field into the following six classes:

1. "Dead" bushes: plants which had shed all their leaves. To determine whether a bush is really dead or not is a difficult matter, for apparently dead plants may throw up new foliage shoots after rain. As a matter of convenience all defoliated plants were grouped together. Some of these were undoubtedly dead, others moribund, but others were probably only in an anabiotic state. There is a colour difference between a dead twig and a living one. When dead the twig sheds its bark, the wood becomes dark on the outside and, when broken, is white and dry. The living defoliated twig is covered with a grey scurfy bark; when fractured it is yellowish and more or less sappy.

2. Very sparsely foliated bushes: plants with leaves on less than 20% of the shoots.

3. Sparsely foliated bushes: plants having less than 50%, but more than 20% of the shoots foliated. Vegetative vigour lacking. Leaves lacking the greenness of the turgid state, distinctly grey, even white in a bright light. Terminal shoots showing curling suggestive of wilting, well seen in the male inflorescences which bend over and become dry. Fallen leaves are common below the bush.

4. Well foliated bushes: plants with 50% or more of the twigs foliated, but lacking the uniform vigour of the next class, that of the fully foliated plants. In this class were also included certain plants which, though they have rather less than a 50% foliation, showed a vigorous development of new greenish shoots.

5. Fully foliated bushes: plants of whatever size bearing abundant foliage up to the apices of almost every twig. Leaves turgid and green-grey. Flowers or fruits, when present, turgid, the terminal male inflorescences standing erect on sappy stems. In this class were included occasional plants with a small degree of defoliation on some twigs, but vigorous growth and abundant fruit and flowers on all other branches.

6. Seedlings: in addition to seedlings proper, very young plants less than a decimetre high and obviously immature were included here.

Types of these six classes are illustrated on Plate viii. It should be noted that these photographs were taken on the same day, within a short distance of each other, also that during the preceding twelve months only 88 points of rain had fallen.

In the field the plants counted were grouped under these six headings and in the many readings made by the field officer considerable proficiency in classifying the bushes was obtained. Clearly the classes are purely arbitrary and grade into one another, but we seldom had any difficulty in deciding to which class a given bush belonged.

For the statistical treatment of the results these six classes have been reduced to four. There was an advantage in maintaining a more finely divided scale of classification in the field than was needed for the subsequent treatment of the figures. It helped to keep the observer on the alert. The four classes are:

1. Defoliated plants: plants classed as "dead" in the field notes. In presenting the results it is preferable to use a purely descriptive term which has no other implication.

2. Wilting plants: includes all those bushes listed as "sparsely foliated" and "very sparsely foliated". The remaining foliage of these plants had entered on a phase of permanent wilting, and the greater part of the plant is in the anabiotic state if not actually moribund.

3. Healthy plants: includes all plants listed as "well foliated" or "fully foliated". Such plants are obviously in a state of vegetative vigour and contrast sharply with the two preceding classes.

4. Seedlings: as defined above.

Having established a scale of vigour, a search was made for a method which would give sufficient samples of the plant population in the four zones to admit of statistical treatment. In the large areas investigated, quadrat methods are unsatisfactory. Finally a modification of the line transect was adopted. Any method adopted had to be one that a solitary observer¹ could use. Laying or stretching a tape over an extent of saltbush for a distance of two miles or more was out of the question. The method adopted, then, was as follows:

Starting from a watering place the observer took a compass bearing and walked into the paddock placing pegs at 100 pace intervals along the line of march. The pegs used were 6 feet high with the top 2 feet painted white. The lines were of variable length according to circumstances. Some extended as much as $2\frac{1}{2}$ miles from the watering place, others less. The ungrazed country, classified as D Zone, lay beyond the ends of the transects, 4 to 5 miles from the water.

The unit of length adopted was the observer's full stride, which we term the pace. This is a long one, 1.5 yards (54 inches). The full stride was deliberately adopted because it was found easier to maintain this at a constant length when continually stopping and starting than any arbitrary pace.

Having established his line of pegs the observer would return to the starting point and "pace" along the line, always keeping two or more pegs in line before him. On specially prepared record sheets he entered every bush which was *actually crossed* by his line of march, the unit being the pace. Notes were also made as to the vigour and size of each bush recorded. The record sheets were uniform foolscap size; portion of one, transcribed from an actual page, is shown in Text-figure 5.

It will be seen that the transect is really a strip transect of a width determined by the observer, who had to judge whether or not a particular bush was actually cut by his line of march. Obviously there might be a certain amount of selection but, since all records were made by the same individual, the error, if such there be, is likely to be uniform. The results are remarkably consistent, e.g., the D Zone in St. Patrick's was surveyed twice, in August, 1929, and November, 1930, when the mean number of plants per 100 paces was 181 ± 19 and 181 ± 21 respectively.

From each watering place three or four such line transects were laid down radiating into the paddock. It was by no means easy to get clear runs of salt-

¹This is a fitting place to pay tribute to the energy and enthusiasm of the field officer, T. B. Paltridge, who lived three years at the Koonamore Vegetation Reserve. Paltridge set out and surveyed all the transect lines described in this paper as well as several other systems not mentioned here. We have jointly and individually visited most of the transects with him more than once and have discussed the work with him in the field at all stages of its progress. To Paltridge, however, fell the task of recording the data under difficult conditions and sometimes with no small physical discomfort.—T.G.B.O. and J.G.W.

bush about 2 miles long without some physiographic variations, i.e., flooded areas, watercourses or rocky outcrops, and at the same time avoid feeding grounds from other waters. The five transect systems described are free from objections of this type. In the case of the Melton transects to be described later, a variation

St. Patrick's Paddeck Page 4

Open Transect No. 4 15 7 11529

No. of Paces	Plant	Dist. to C.M.	Height in C.M.	Diam. in C.M.	Mooring	Damping	Foliation			Remarks
							Top	Frame	Dist.	
60	<i>Atriplex</i>		30	2.8	✓					
60	"		30	30					✓	
60	"	✓			✓					✓
60	"	✓								
64	"	✓								✓
64	"	✓								✓
64	"	✓								✓
65	"	✓	25	25				✓		
65	"	✓								✓
65	"	✓								✓
65	"	✓	15	15				✓		
68	"	✓								✓
68	"									Seedling.
69	"	✓								

Text-fig. 5.—Portion of an actual record sheet.

of the line transect was used. The original line from the watering place was laid down and counts made along it as usual, but, in addition, at every 200-pace interval a cross transect at right angles to the main transect was run for 300 paces. This method is considered to be superior to the system of radiating lines, as more samples within the different zones can be obtained.

For comparison of the different classes of plants in the different zones, the number of bushes per 100 paces was treated as a unit and sheets drawn up showing the total number of plants, the number of defoliated, of wilted, of healthy plants and of seedlings per 100 paces.

There were now available for each zone a number of 100-pace unit samples of the population and from these figures the following statistics were calculated for each class: the mean per 100 paces, the standard deviation of the mean, and the standard error of the mean. Comparisons of the mean number of plants of any class in different zones could then be made by use of the difference of means and their standard error of difference, a difference being regarded as significant if the difference of the means exceeded twice the standard error of difference. A standard error of grouping was also calculated and the grouping is sufficiently fine in all cases dealt with except in that of the seedlings, which, unless otherwise mentioned, are not considered in the following discussion of the results. Sufficient samples were obtained to take into account any variations due to physiographic influences.

RESULTS.

In the following tables the \pm sign is given before the standard deviation and standard error of the means, and also the standard error of difference, in the first line only. It is to be understood as referring to all figures in the respective columns. In the columns giving the difference of the means a significant difference

is printed in bold type with a + or - sign preceding it, denoting a significant increase or a significant decrease in the mean numbers of plants in the classes considered.

The first desideratum is a comparison of the grazed and ungrazed country. It is difficult in a general way to make a direct comparison, for example, between the heavily-grazed zones in different paddocks on account of different intensities of stocking. It has been pointed out previously that the extent of the heavily-grazed zone varies with the number of sheep watering on any particular place. But, in the first instance, it seemed desirable to present all our data in a uniform fashion and then to point out where the grouping has been too coarse on account of lighter stocking in certain instances.

Quite apart, therefore, from our knowledge of the grazing intensities about different watering places, we have grouped the four zones as follows:

- A Zone* (Pl. ix, fig. 1).—The heavily trampled and over-grazed zone close to the watering place (0–300 paces).
- B Zone* (Pl. ix, fig. 2).—Moderately heavily grazed zone, extending to 1 mile from the well (300–1,200 paces).
- C Zone* (Pl. ix, fig. 3).—Lightly grazed zone (1,200 paces to end of transect line; usually another mile).
- D Zone* (Pl. ix, fig. 4).—Unstocked zone (at least 4 miles from the watering places).

Five main transect systems have been carried out on Koonamore and two neighbouring sheep stations. These represent four different systems of stocking. The names and characteristics of the systems are outlined below. Stocking figures furnished to us by courtesy of the different station managers only served as very rough guides. They give the number of sheep in the paddock month by month. But, as there may be two or more watering places in the one paddock, it is impossible to say how many sheep are actually watering at a particular bore. We do not, therefore, give any actual figures of numbers of sheep, but from all the information at our disposal classify the type of stocking as heavy, light and so on.

The five transect lines are:

Koonamore Station.

1. Alderman's Paddock System. Heavily and consistently stocked.
2. St. Patrick's Paddock System. Lightly stocked, being held as a reserve or ram paddock.
3. X-Ray Well System. Heavily but intermittently stocked owing to the uncertain water supply obtainable from the well.

Melton Station.

4. Putt's Well System. Heavily and consistently stocked.

Mutooroo Station.

5. West Bore Hole Dam System. Very lightly stocked.

The D Zone (Unstocked).

The saltbush community in this zone represents approximately the virgin state of the community untouched by sheep, and, since it serves as the basis for comparison with the other grazed zones, will be considered first.

As might be expected, the "open transects" taken at approximately the same time in different regions are all comparable and show no significant differences in the mean number of plants for the different categories as the following tables show.

November, 1930.

			Melton System.			St. Patrick's System.			Differences.	
			M	σ	S.E.	M	σ	S.E.	M	S.E. of D.
Total Plants	..	..	163	± 13	± 5.8	181	± 21	± 6.6	18	± 8.9
Defoliated Plants	..	..	94	15	6.9	115	26	5.8	21	9.2
Wilting Plants	..	..	24	5	2.4	16	5	1.2	+ 8	2.8
Healthy Plants	..	..	43	17	7.4	45	12	2.7	2	7.9
Seedlings	..	..	3	1.7	0.7	7	6	1.1	4	1.3
			N=5			N=20				

Only in the case of the wilting plants is there a significant increase in these two transects, and the means in this class are low. The difference between the total plants and the defoliated plants is barely significant.

The X-Ray transects run in April, 1930, are comparable with those at Mutooroo run at the same date.

			X Ray System.			Mutooroo System.			Differences.	
			M	σ	S.E.	M	σ	S.E.	M	S.E. of D.
Total Plants	..	..	173	± 25	± 9.4	149	± 38	± 10.1	24	± 14.0
Defoliated Plants	..	..	126	17	6.6	101	29	7.7	+25	10.2
Wilting Plants	..	..	23	14	5.3	32	14	3.8	9	6.5
Healthy Plants	..	..	18	9	3.3	16	10	2.7	2	4.2
Seedlings	..	..	6	4	1.6	—	—	—	6	—
			N=7			N=14				

Again there is no significant increase in any category, except perhaps in the case of defoliated plants which are somewhat greater in the X-Ray System, but the difference of the means is barely significant.

If, however, an open system from the first group is compared with that of the second, e.g., St. Patrick's with X-Ray, it will be seen that significant differences have taken place in the vigour of the community, notably in the increase in the number of healthy plants. This is due to the rains between the two periods at which the transects were run. This difference is best seen in a comparison of the two sets of results from the ten transects run in the unstocked country in St. Patrick's Paddock. One set was obtained in August, 1929, towards the end of 12 months, in which only 88 points of rain fell, no fall being greater than 25

points, and the other in November, 1930, after a year's good season with effective rains. These are compared in the following table:

	August, 1929.			November, 1930.			Differences.	
	M	σ	S.E.	M	σ	S.E.	M	S.E. of D.
Total Plants ..	181	± 19	± 4.5	181	± 21	± 6.6	0	± 7.9
Defoliated Plants ..	83	13	2.9	115	26	5.8	+32	7.6
Wilting Plants ..	65	12	2.7	16	5	1.2	-49	2.9
Healthy Plants ..	17	10	2.2	45	12	2.7	+28	3.4
Seedlings ..	15	8	1.9	7	6	1.1	8	2.2
N = 20				N = 20				

Here it will be seen that there is no significant increase in the mean number of total plants, but there is an increase in the number of defoliated plants and of healthy plants and a decrease in the number of wilting plants, i.e., some of the wilting plants have formed vigorous bushes following the rains and others have died.

Summarizing the results of the analysis of the bush in unstocked country, these transects in widely separated regions enable us to show that at any period the composition of the community from the point of view of vigour remains the same. The outstanding feature of the community is the large number of defoliated and moribund plants.

The A Zone (Heavily overstocked zone).

This zone is formed immediately around the watering places, usually for a distance of about 300 paces. The inevitable heavy stock effect due to the congregation of sheep at the troughs results in the complete removal of the permanent vegetation for some distance. From this bare area the number of bushes per 100 paces increases rapidly until this zone merges into the B Zone or heavily grazed zone. The A Zone is, therefore, really a composite of several very narrow zones, the plant cover of which ranges from zero to an area well covered with bushes, according to the decreasing degrees of severity in the stock effect. The A Zone cannot, then, be treated statistically, since the standard deviations are necessarily large. Its features are shortly described below.

The number of bushes is low compared with either the grazed or the ungrazed zones. Such bushes as exist are either healthy, for they are necessarily very widely spaced, or else moribund and in process of being knocked out by the sheep. Obviously the extent of this zone will vary with the degree to which the paddock is stocked. Its width, indeed, is a valuable guide to the severity of the stocking. Further, this bare area, even though relatively small, may have an influence of the utmost importance on the surrounding vegetation. The removal of the plant cover from a localized area such as this may initiate an area of sand-drift or an area in which dust storms originate. The effect of the drift started in this way is cumulative and the denuded area gradually extends owing to the blast of sand killing and removing plants that, but for its

action, would tend to encroach on the bare area. When the surface soil is removed, there remains a hard unproductive subsoil—often composed largely of travertine limestone—which is practically incapable of supporting vegetation and from which the run-off following rain is high. Plate vii, figure 4 shows a denuded area extending more than a mile from the bore. This waste was developed within a short time, whilst our investigation was in progress, as a result of watering 6,000 sheep for three months during a drought at what was, at the outset, a newly sunken well with saltbush right up to the troughs. The control of stocking should certainly aim at preventing an undue extension of the bare area. Occasional "spelling" of a watering place, i.e., closure of all access by stock to the dam or drinking troughs, is beneficial. The trampling by sheep plants a considerable number of saltbush fruits around the outer portions of this zone (cf. X-Ray System below). Given the opportunity these will develop into bushes that will check the drift.

The B Zone (Heavily-grazed zone).

This zone, as described previously, is taken in the first instance as extending to 1,200 paces (1 mile) from the watering place. Considerations of the changes in this zone must take account of the degree to which the paddocks have been stocked. The changes in composition of this zone are made clear by comparison with the state of the ungrazed country. Tables showing this comparison in different paddocks are presented below.

1. *Melton System*, under heavy grazing conditions, run in November, 1930.

	B Zone.			D Zone.			Differences.	
	M	σ	S.E.	M	σ	S.E.	M	S.E. of D.
Total Plants ..	181	± 51	± 9.1	163	± 13	± 5.8	18	± 10.9
Defoliated Plants ..	66	38	8.3	93	15	6.9	-27	10.7
Wilted Plants ..	21	14	3.1	24	5	2.4	3	3.9
Healthy Plants ..	74	15	3.3	43	17	7.4	+31	8.1
Seedlings ..	6	6	1.4	3	1.7	0.7	3	1.6

N=30

Compared with the ungrazed country, the heavily-grazed zone shows a significant decrease in the mean number of defoliated plants and a significant increase in the mean number of healthy plants.

2. *St. Patrick's System*, under light grazing conditions.

For this paddock, two sets of readings of the transect system are available, the first run in October, 1929, towards the end of fifteen months' severe drought and the other, after the rains, in November, 1930, after 12 months of average rainfall. For uniformity, in the first instance the B Zone is taken as the same length as in the other systems, namely, for 1,200 paces from the well. Comparisons of this grazed zone with the unstocked country are shown in the following tables:

October, 1929.

		B Zone.			D Zone.			Differences.	
		M	σ	S.E.	M	σ	S.E.	M	S.E. of D.
Total Plants	..	189	± 65	± 10.8	181	± 19	± 4.5	8	± 11.2
Defoliated Plants	..	54	40	6.6	83	13	2.9	-29	7.2
Wilting Plants	..	91	49	8.2	65	12	2.7	+26	8.6
Healthy Plants	..	40	23	3.8	17	10	2.2	+23	4.4
Seedlings	.. ..	5	5	0.8	15	8	1.9	10	4.0

N=36

November, 1930.

		B Zone.			D Zone.			Differences.	
		M	σ	S.E.	M	σ	S.E.	M	S.E. of D.
Total Plants	..	207	± 42	± 7.0	181	± 21	± 6.6	26	± 9.6
Defoliated Plants	..	81	33	7.7	115	26	5.8	+34	9.4
Wilting Plants	..	35	15	3.3	16	5	1.2	+19	3.5
Healthy Plants	..	90	45	9.0	45	12	2.7	-45	9.4
Seedlings	.. ..	4	4	0.9	7	6	1.1	3	1.4

N=36

The results in the two cases are the same; that is, that both during drought and during a rainy season the heavily-grazed zone shows a significant decrease in the mean number of dead plants and a significant increase in the mean number of healthy plants as compared with the ungrazed country. There is no marked alteration in the total number of plants, though the 1930 reading does show an increase. In both cases there is also a significant increase in the mean number of wilting plants in the grazed zone. This increase, however, is largely fictitious, for it is due to too coarse grouping of the two grazed zones. St. Patrick's Paddock has been very lightly stocked and it is known that the maximum grazing does not extend as far as 1,200 paces. It will be seen later that a large percentage of the plants are classed as wilting in the C, or lightly grazed, zone and this is reflected in figures above.

Shortening the zone by 400 paces in the case of St. Patrick's Paddock because of light stocking we get the following figures for the 1929 series:

		B Zone.			D Zone.			Differences.	
		M	σ	S.E.	M	σ	S.E.	M	S.E. of D.
Total Plants	..	175	± 39	± 4.9	181	± 19	± 4.5	6	± 6.7
Defoliated Plants	..	35	17	3.5	83	13	2.9	-48	4.5
Wilting Plants	..	74	32	6.5	65	12	2.7	9	7.0
Healthy Plants	..	61	11	2.3	17	10	2.2	+44	3.0
Seedlings	.. ..	5	5	1.0	15	8	1.9	10	3.4

N=20

In this case the shortening of the B Zone, which we know actually does occur, brings the results exactly in line with the figures obtained from the Melton transects, namely, that there is a significant decrease in the mean number of defoliated plants and a significant increase in the mean number of healthy plants.

3. *The X-Ray Well System*, under intermittent heavy grazing conditions. Transects run in November, 1930. Comparisons of the heavily grazed and ungrazed zone are shown in the following table:

	B Zone.			D Zone.			Differences.	
	M	σ	S.E.	M	σ	S.E.	M	S.E. of D.
Total Plants ..	196	± 34	± 6.8	173	± 25	± 9.4	23	± 11.6
Defoliated Plants ..	86	24	4.7	126	17	6.6	-40	8.1
Wilting Plants ..	23	18	3.6	23	14	5.3	0	6.3
Healthy Plants ..	62	61	12.2	18	9	3.3	+44	12.6
Seedlings	29	20	4.0	6	4	1.6	+23	4.3

N=36

Under these conditions the same effects are found, namely, that there is a significant decrease in the mean number of defoliated plants and a significant increase in the mean number of healthy plants in the grazed zone. In addition an important fact is the significant increase in the mean number of seedlings. This is the only case where a reliable measure of seedling variation has been obtained in our investigations. It is due to the intermittent nature of the stocking which allows seedlings to grow from seed planted by the trampling of the sheep.

There remain for consideration two somewhat special cases of the B Zone. One is a system in Alderman's Paddock, where the stocking is heavy but the feeding grounds are restricted owing to the presence near the well of steep and rocky hills on which sheep do not feed. The second is a system on Mutooroo where the stocking is exceedingly light.

4. *Alderman's Transect System* shows no differences from the other figures presented, except that there is a significant decrease in the mean number of total plants in the grazed zone compared with the ungrazed zone. Owing to this difference in total numbers the number of plants in the different categories are expressed as percentages of the total numbers of plants. The decrease in total numbers is due to the consistent heavy stocking of this paddock, which tends to remove the dead plants by mechanical means. The figures for the B Zone (to 1,200 paces from the dam) and the ungrazed country are shown in the following table:

	B Zone.			D Zone.			Differences.	
	M	σ	S.E.	M	σ	S.E.	M	S.E. of D.
Total Plants ..	136	± 40	± 6.8	181	± 19	± 4.5	-45	± 9.3
Defoliated Plants %	16	7.3	2.7	45	6	1.4	-29	3.0
Wilting Plants %	41	13	2.1	36	5	1.9	5	2.8
Healthy Plants %	25	12	2.0	9	5	1.1	+16	2.3
Seedlings % ..	16	13	2.1	8	4	1.0	8	2.3

N=36

These figures confirm those given previously, namely, that the B Zone is characterized by a significant decrease in the number of defoliated plants and a significant increase in the number of healthy plants when compared with the ungrazed country.

5. *Mutooroo Transect System* shows a variation in the B Zone from those so far considered. This has been so lightly stocked that it differs little from the ungrazed country; but the figures are interesting in that they show the first effect of grazing on virgin country, which consists in the removal of dead bushes. The stocking has not been sufficiently heavy to cause an improvement in the vigour of the bush. Comparisons of the grazed and ungrazed zones are given in the following table:

			B Zone.			D Zone.			Differences.	
			M	σ	S.E.	M	σ	S.E.	M	S.E. of D.
Total Plants	..	104	± 40	± 9.0	149	± 38	± 10.1	-45	± 13.5	
Defoliated Plants	..	69	29	6.4	101	29	7.7	-32	10.5	
Wilting Plants	..	27	13	3.0	32	14	3.8	5	4.8	
Healthy Plants	..	9	5	1.4	16	10	2.7	7	3.3	
Seedlings	.. ..	—	—	—	—	—	—	—	—
N=18										

The features of the heavily-grazed zone are, then, a large increase in the mean number of healthy plants and a corresponding decrease in the mean number of defoliated plants. This zone is regularly stocked in all paddocks carrying sheep, though not necessarily consistently, as sheep tend to herd together and the mob will feed in different parts of this region at different times.

The first effect of grazing, as seen in Mutooroo, consists in the mechanical removal of dead bushes. The second effect under heavy grazing is the marked improvement in the vigour of the bush compared with the unstocked bush. This improvement of the bush is due to pruning; the constant removal of the terminal buds stimulates development of lateral shoots so that more compact, vigorous bushes result. These bushes stand in marked contrast to those of the ungrazed country which are sparse and twiggy. This result in the B Zone is, indeed, one of the most important results that have been brought to light in these investigations, viz., that under moderately heavy stocking the mean total number of plants per 100 paces is not increased compared with the ungrazed country, but the health and vegetative vigour of the community is increased and the area thus becomes more valuable for grazing. Obviously the grazing must not be too heavy or the stock effect will become destructive to the community and thus bring about A Zone conditions leading to an extension of the bare area.

A third point of importance is that intermittent stocking is valuable in that it allows seedlings to become established. This point is well shown by the figures of the X-Ray Well System. It would appear that heavy intermittent stocking is the most desirable type of stocking in saltbush country.

In both cases a significant increase in the mean number of wilting plants per 100 paces is apparent in the lightly-grazed zone compared with the unstocked country. A significant increase in the number of plants is shown in the 1929 transects, but not in the 1930 transects: this is probably due to the fact that the 1930 figures are less reliable, since only 9 samples for this zone are available in this year. The 1929 figures also show an increase in the number of defoliated plants. It was pointed out, in dealing with the B Zone of this transect system, that this grouping is artificial and does not express the true relation of the zones which are telescoped under light stocking and do not extend outwards from the watering place so far as they do when heavier stocking occurs. Taking the C Zone as extending from 800 paces only, instead of 1,200 paces (it will be remembered that the B Zone of this system was so shortened), we obtain the following figures:

		C Zone.			D Zone.			Differences.	
		M	σ	S.E.	M	σ	S.E.	M	S.E. of D.
Total Plants	..	234	± 55	± 10.6	181	± 19	± 4.5	+53	± 11.5
Defoliated Plants	..	93	27	5.2	83	13	2.9	10	6.0
Wilting Plants	..	109	50	9.6	65	12	2.7	+44	9.9
Healthy Plants	..	26	21	4.0	17	10	2.2	9	4.9
Seedlings	.. ..	7	4	0.8	15	8	1.9	8	4.0
N=27									

This somewhat finer grouping shows a significant increase in the mean total number of plants and in the wilting plants in the lightly grazed zones and is exactly comparable with the Melton results.

3. *Alderman's Transect System.*—As the St. Patrick's System needed a modification of the uniform width of the zones owing to light stocking, so also the Alderman's System needs modification because of the heavy stocking and peculiar physiographic conditions of this paddock. It has been mentioned previously that the feeding ground of this water is restricted, owing to the presence of high hills near the bore, and in addition this paddock has always been heavily stocked. We know that the heavily-grazed zone around this watering place extends for about 2 miles. This is shown clearly in the analysis of the figures for the different classes of plants on the original uniform basis (that is, B Zone extending one mile from the bore, the C Zone about two). The figures on this basis are shown in the following table, in which the B and C zones are compared, using percentages since the total numbers of plants in the two zones are not the same:

	B Zone (300-1,200 paces).			C Zone (1,200-2,000 paces).			Differences.	
	M	σ	S.E.	M	σ	S.E.	M	S.E. of D.
Total Plants ..	136	± 4.0	± 6.8	193	± 76	± 13.6	+57	± 15.2
Defoliated Plants %	16	7.3	2.7	21	12	2.1	5	3.4
Wilting Plants %	41	13	2.1	44	13	2.3	3	3.1
Healthy Plants % ..	25	12	2.0	27	13	2.3	2	3.0
Seedlings % ..	16	13	2.1	6	3	0.9	10	2.2

It will be seen that there is an increase in the total number of plants, but no increase in any other category. In other words, the composition of the two zones is the same so far as vigour is concerned and the effect of lighter stocking has not been reached. The B Zone was therefore lengthened to 2,000 paces from the well (which corresponds with our knowledge of the usual feeding grounds) and the C Zone taken beyond this from 2,000-3,000 paces. The C Zone compared with the unstocked country then falls into line with the Melton and St. Patrick's transect system, as is seen in the following table:

	C Zone.			D Zone.			Differences.	
	M	σ	S.E.	M	σ	S.E.	M	S.E. of D.
Total Plants ..	246	± 60	± 16.2	181	± 19	± 4.5	+65	± 16.8
Defoliated Plants ..	30	9	2.5	45	6	1.4	-15	2.9
Wilting Plants ..	49	12	3.2	36	8	1.9	+13	3.7
Healthy Plants ..	16	14	4.0	9	5	1.1	7	4.1
Seedlings	4	7	2.2	8	4	1.0	4	2.4

4. *The Mutooroo System.*—These paddocks have been so lightly stocked that no C Zone is present. Beyond 1,200 paces from the well the community has the same structure as regards vigour as the country further distant from the well. The following comparison is between zones between 1,200 to 2,000 paces from the well and 2,000 and 3,400 paces from the well. There is no difference, as will be seen:

	C Zone.			D Zone.			Differences.	
	M	σ	S.E.	M	σ	S.E.	M	S.E. of D.
Total Plants ..	137	± 42	± 8.3	149	± 38	± 10.1	12	± 12.7
Defoliated Plants ..	102	25	5.0	101	29	7.7	1	9.6
Wilting Plants ..	23	10	1.9	32	14	3.8	9	4.3
Healthy Plants ..	12	12	2.4	16	10	2.7	4	3.6
Seedlings	—	—	—	—	—	—	—	—

N=14

N=14

It will be seen from the foregoing that the outstanding features of the lightly-grazed zone are an increase in the mean total number of plants per 100 paces and an increase in the mean number of wilting plants when compared with the unstocked country. That is to say, under light grazing conditions, the community shows a deterioration when compared with the virgin ungrazed community. The bushes are overcrowded, due to occasional trampling which results in the planting of seed, and the plants have not even the vigour of the ungrazed communities, which, as has been shown, is small compared with the heavily-grazed zones. This increase in wilting plants probably follows from undue competition as a result of overcrowding of the bushes.

It follows, therefore, that light grazing of saltbush is more harmful to the vigour of the community than heavy stocking or than no stocking at all.

SUMMARY.

1. The investigations described in this paper were carried out at the Koonamore Vegetation Reserve, in the north-east of South Australia, during the period April, 1928, to June, 1931. They form part of a more extensive programme having as its object the study of the arid flora of this area. The Reserve forms the Arid Flora Research Station of the University of Adelaide. The work described herein has been carried on with the aid of a grant from the Commonwealth Council for Scientific and Industrial Research.

2. *Atriplex vesicarium* Heward, the perennial saltbush, is the dominant plant over the extensive shrub steppe formation that is developed in the north-east of South Australia and many other portions of arid Australia. The community is an open one composed of gregarious low-growing bushes (32×34 cm.) with much bare ground between the small groups.

3. The plants have usually a number of slender, brittle stems branching freely at the base. The leaves are non-cuticularized, tomentose with densely packed bladdery hairs and somewhat succulent, but with a high osmotic pressure (50 atmos.). The transpiration rate is low and the leaves are able to absorb moisture from the air with 85% saturation. The root system is extensive but superficial (10–20 cm.). Deciduous feeding roots are a feature of the main framework, and the root system is probably non-functional during droughts.

During prolonged rainless periods the leaves pass into a state of permanent wilting, which is delayed by their capacity to gain water from damp air. Ultimately they are exfoliated and the plant passes into a leafless state of anabiosis.

4. Climatic data given show that the diurnal range of temperature is great and, as a consequence, the relative humidity at times of low temperature is surprisingly high. The mean annual maximum is 85%, a figure that is maintained for an average of 3 hours in summer to as much as 9.5 hours in winter.

It follows, therefore, that the saturation deficit is low (0.08 to 0.02 inch of mercury) for at least a portion of each day. Under such conditions *Atriplex* leaves absorb water. On the contrary, of course, the saturation deficit is high (0.95–0.65 for a portion of each day from October to April inclusive) which indicates the aridity of the climate. The period covered by the investigation has been one of severe drought which has accentuated the stock effect.

5. The north-east district of South Australia is leased as large sheep stations which are subdivided into paddocks seldom less than 20 square miles in area. These are provided with one or more watering places, dams or bores. Natural

permanent water is almost unknown. As the distance that sheep travel from water is seldom more than 3 miles, it follows that those portions of a paddock near water are grazed and trampled by sheep (stock effect) much more intensively than others remote from the water which may be seldom or never grazed at all.

6. Starting then at a watering place and walking to the most remote portion of the paddock, saltbush will be traversed that is subjected to all degrees of stocking intensity, ranging from the inevitable over-stocking at the drinking place to practically virgin country. Four zones of decreasing severity in stock effect are recognized:

The A Zone, immediately around the watering place.

The B Zone, on main feeding grounds of the sheep.

The C Zone, beyond B, which is only lightly grazed.

The D Zone, still more remote and virtually ungrazed.

This last zone gives a measure of a saltbush population on which the sheep portion of the biota does not operate.

7. Systems of transect lines have been run from several watering places on different stations to secure variation in type of country and management. Along these lines the number of saltbushes and the vegetative vigour of each bush according to a predetermined scale has been ascertained. The unit of length is the "pace" (a stride of 1.5 yards). Transect lines have been run for distances of from 1,200 to 3,000 paces from different waters. The results so obtained have been considered in groups of successive 100-pace intervals. A sufficient number of such 100-pace intervals has been obtained from each zone to allow of a comparison of the zones by the difference of the means. Transect readings obtained in the D Zone, 3-5 miles from water, provide the standard of the unstocked community.

8. As would be expected, the D Zones in different areas are comparable, showing neither a significant difference in the mean number of bushes per 100 paces, nor in the health and vigour of the community. A characteristic feature of the community during the drought is the high proportion of defoliated and dead plants. The A Zone is not treated statistically owing to the wide variations in the readings. This is only natural round the drinking place, owing to the excessive stock effect.

9. The B Zone, moderately heavily grazed, shows no significant difference in the mean number of plants per 100 paces when compared with the ungrazed country, but does show a significant increase in the mean number of healthy plants and a corresponding significant decrease in the mean number of defoliated and dead plants. We thus reach the important conclusion that there is a measurable increase in the health and vegetative vigour of the community as a result of moderately heavy grazing even during a drought.

10. The C Zone, lightly grazed, on the other hand, shows a significant increase in the mean number of bushes and in the mean number of wilting plants per 100 paces. The lightly stocked saltbush community is thus less healthy than the moderately heavily stocked community or even than the community that is not stocked at all. This we attribute to the planting of seed by the hooves of sheep and the failure to remove moribund plants by light trampling, thus leading to an overcrowded community in which the competition is unduly severe.

11. Evidence is presented from an intermittently but heavily stocked water, the X-Ray Well transect system, that this type of stocking is most beneficial to the vegetative vigour of the saltbush. It prunes the bushes, tramples out the weakly ones, plants seed which has time to germinate and form established plants before the next stocking period.

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EXPLANATION OF PLATES VII-IX.

Except where otherwise stated all photographs taken by T.B.P.

Plate vii.

Fig. 1.—Shrub-steppe of *Atriplex vesicarium* photographed by T.G.B.O. on 19th August, 1923. Rainfall 583 points during previous twelve months.

Fig. 2.—Photograph taken from approximately same position as that in Fig. 1, during August, 1929. Rainfall 88 points during previous twelve months.

Fig. 3.—View over Salt Creek No. 1 quadrat from N.E. corner peg. The strings are stretched dividing the area into 1-metre squares. Note the gregarious habit of the *Atriplex* and the high proportion of sparsely foliated (wilting) bushes. Photographed 19th September, 1928.

Fig. 4.—General view taken from the windmill tower of a well showing complete destruction of *Atriplex* owing to unduly heavy stock effect. Most of this damage was done within three months. Photographed by T.G.B.O., 7th June, 1929.

Plate viii.

Note.—Photographs in Figures 1-5 were taken in Alderman's Paddock, Koonamore Station, on 26th August, 1929.

Fig. 1.—"Dead" bush, i.e., defoliated type.

Fig. 2.—"Very sparsely foliated bush", a constituent of the "wilting" class.

Fig. 3.—"Sparsely foliated bush", a constituent of the "wilting" class.

Fig. 4.—"Well foliated bush", a constituent of the "healthy" class.

Fig. 5.—"Fully foliated bush", a constituent of the "healthy" class.

Fig. 6.—"Seedling" saltbush, photographed 4th December, 1929.

Plate ix.

Note.—All photographs on this plate were taken along the Putt's Well transect system, Melton Station, on 30th November, 1930.

Fig. 1.—The A Zone, heavily trampled and overgrazed. Photograph taken within 200 paces of the well. Note that all *Atriplex* bushes have been destroyed.

Fig. 2.—The B Zone, moderately heavily grazed. Photograph taken between 600 and 800 paces from the well. Note the healthy stand of *Atriplex*, most of the bushes showing vegetative vigour.

Fig. 3.—The C Zone, lightly and occasionally stocked. Photograph taken between 1,500 and 1,700 paces from the well. Note the overcrowded state of the community, with a high proportion of lightly foliated bushes.

Fig. 4.—The D Zone, virtually ungrazed. Note the almost leafless state of the bushes which are less crowded than they are in the C Zone.
